Executive Summary

Purpose

This Feasibility Study (FS) develops and evaluates remedial alternatives for mitigating soil and groundwater contamination at Environmental Restoration Program (ERP) Site SD-10 (Site 10), located at Beale Air Force Base (AFB or Base), California.

The FS is one of several steps that comprise the Comprehensive Environmental Restoration, Compensation, and Liability Act (CERCLA) of 1980 process. Although Beale AFB is not on the National Priorities List, the Air Force implements the ERP in a manner consistent with CERCLA guidance and policy.

The information presented in this FS will be used to help decision-makers select the preferred remedy for mitigating contamination in the study area. The preferred remedy will be presented to the public in a Proposed Plan. After public comments are received, the final remedy selection will be documented in the Record of Decision (ROD).

Site Description

Beale AFB is located in Yuba County, California, approximately 40 miles north of Sacramento and 10 miles east of Marysville, as shown on Figure ES-1. ERP Site 10 is located in the north-central portion of Beale AFB, east of Doolittle Drive and the Flightline Area. A portion of the site consists of a paved area at the eastern end of Grumman Avenue. The location and layout of the Engine Test Area at Site 10 are presented on Figure ES-2.

Topographic relief in the vicinity of Site 10 is small, with ground surface generally converging toward the central portion of Site 10 then sloping toward the western site boundary. Ground surface elevations range from about 156 feet to about 116 feet above mean sea level. Much of the land in the vicinity of Site 10 is open pasture; however, it is not used for grazing.

Contaminants of Concern

The Engine Test Area at Site 10 was used for testing jet engines from SR-71 aircraft during the period from 1959 to 1990. Two 10,000-gallon aboveground storage tanks (AST) contained the JP-7 jet fuel used for engine test runs. These tanks were located on a hillside above and to the west of the engine test stand (Figure ES-2). Solvents and other cleaning agents were stored in 55-gallon drums on a metal rack near the test stand (CH2M HILL, 1991).

Fuel that was spilled or discharged during the process of engine testing flowed across the concrete pad and eventually washed onto the surrounding ground surface. Most of the fluid eventually discharged to the drainage area southeast of the Engine Test Area. Soil discoloration and petroleum odor has been observed in the drainage ditch near the Engine Test Area

(AeroVironment, 1987). Spills and leaks also occurred during testing operations and impacted soils in the nearby vicinity (Law, 1996b). Potential contaminants include jet fuel, petroleum distallates, soap, oil, and solvents (CH2M HILL, 1991).

In response to the contamination detected in soil and groundwater at Site 10, Beale AFB has implemented a series of actions under the Installation Restoration Program. These actions are ongoing and include site characterization, groundwater monitoring, and installation and operation of a soil vapor extraction (SVE) system.

A Remedial Investigation (RI) report (CH2M HILL, 2002) was prepared to describe the nature and extent of contamination at Site 10 and to assess potential human health risks, ecological impacts, and the potential effects on water resources. Contaminants of concern (COCs) were identified in the RI based on the assessment of potential risks and adverse impacts.

COCs for each media at Site 10 are presented in Table ES-1.

TABLE ES-1
Site 10 COCs for Each Media
Site 10 Feasibility Study, Beale AFB, California

Contaminant	Groundwater	Soil	Soil Vapor
Benzene	X		
Chloroform	X		
cis-1,2-Dichloroethene (cis-1,2-DCE)	X		X
Methyl-tert-butyl-ether (MTBE)	X		
Polynuclear aromatic hydrocarbons (PAHs)		X	
Tetrachloroethylene (PCE)	X		
Trichloroethylene (TCE)	X	X	X
Total Petroleum Hydrocarbons, Diesel Range (TPH-D)	X	X	
trans-1,2-Dichloroethene (tran-1,2-DCE)	X		

With the exception of PAHs in surface soil, none of the COCs for Site 10 was found to present a threat to human health or ecological receptors. PAHs were only a risk in the hypothetical resident scenario. If the land remains industrial, which is likely because of its proximity to the flightline, then PAHs would not be identified as a COC. Other COCs for Site 10 were identified solely on their potential impacts to groundwater quality.

TCE is the most widespread COC in groundwater at Site 10. All other groundwater COCs fall within the area with detectable TCE contamination in groundwater.

Preliminary Cleanup Goals

The preliminary cleanup goals for soil, soil vapor, and groundwater target the COCs described in Table ES-1. Narrative remedial action objectives (RAO) in combination with a review of applicable or relevant and appropriate requirements (ARARs) were used to guide the selection of numerical preliminary cleanup goals. Preliminary cleanup goals should not be considered final cleanup levels to be achieved by remedial action. Final cleanup levels will be contained in the ROD. The cleanup goals established for Site 10 were selected to meet the following specific RAOs:

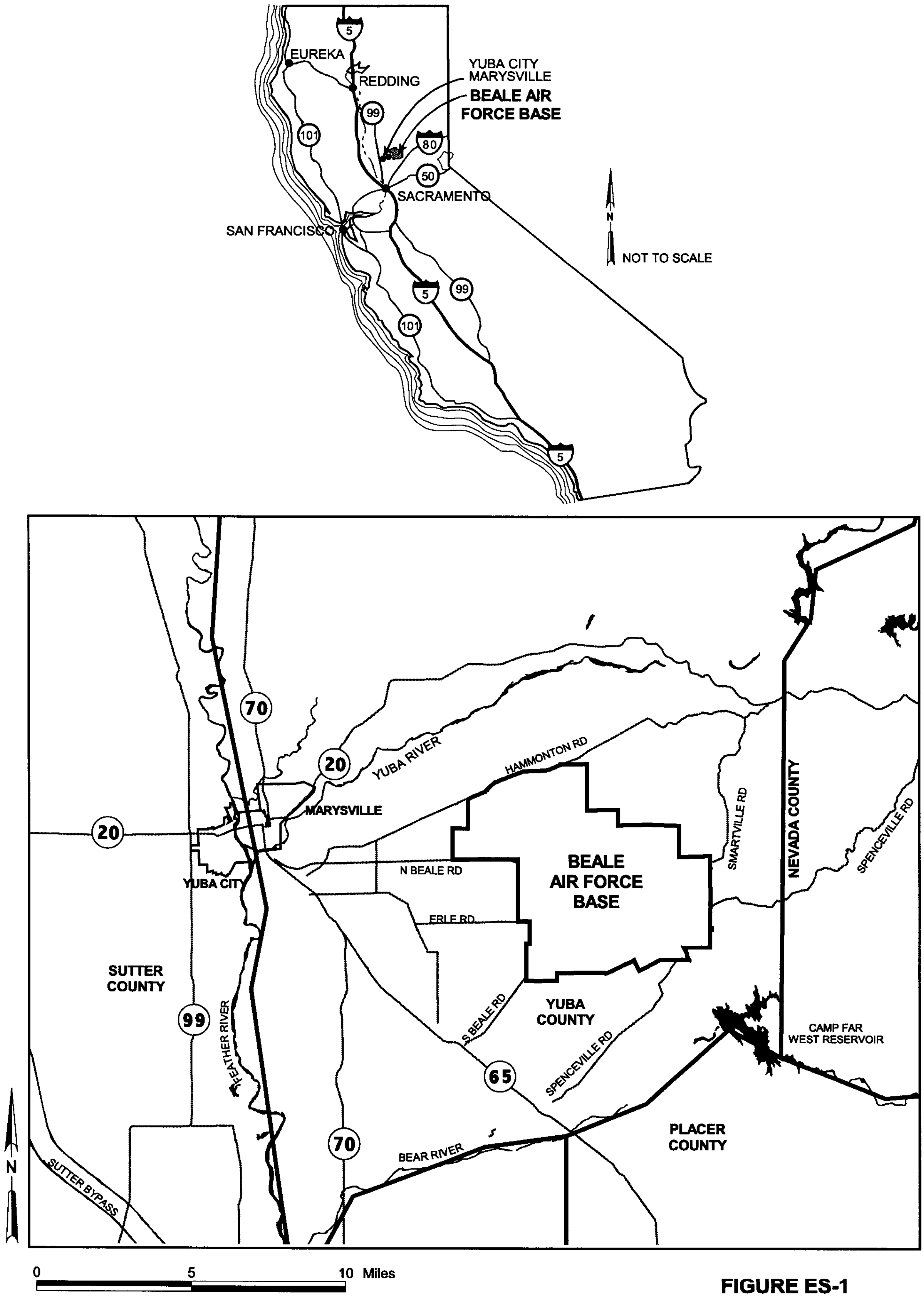

FIGURE ES-1
BEALE AIR FORCE BASE
LOCATION MAP
SITE 10 FEASIBILITY STUDY
BEALE AIR FORCE BASE, CALIFORNIA

CH2MHILL

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- Restore the quality of groundwater at the site so that it is acceptable for designated beneficial uses. Beneficial uses include municipal and domestic water supply, agricultural supply, industrial service supply, and industrial process supply.
- Protect human health by preventing exposure to contaminants in soils that would result in an increased lifetime cancer risk greater than 1×10^{-6} or a hazard index greater than 1 for residential exposure scenario.
- Continue operation of the Site 10 SVE system to remove contaminants from the vadose zone to the extent technically and economically feasible to protect groundwater and to reduce cost and time of groundwater cleanup.
- Prevent the migration of contaminants from soil to groundwater at concentrations that would result in an exceedance of ARARs or risk-based remediation goals.
- Control and/or monitor the migration of groundwater contaminants so that the quality of groundwater at the Base boundary and Base production wells downgradient from Site 10 do not exceed cleanup goals.

Preliminary cleanup goals for volatile organic compounds (VOC) in soil and soil vapor were based on existing criteria established for operation and maintenance of the Site 10 SVE system. These cleanup goals are based on calculated soil vapor concentrations that provide assurances that groundwater quality will not be significantly impacted due to leaching of contaminants from the soil. Cleanup goals for VOCs in soil vapor are presented in Table ES-2.

TABLE ES-2
Preliminary Cleanup Goals for Soil Vapor for VOC COCs
Site 10 Feasibility Study, Beale AFB, California

	Groundwater Criteria		Soil Vapor
Analyte	**Federal MCL (µg/L)**	**State MCL (µg/L)**	**Cleanup Level (ppbv)**
TCE	5	5	350
cis-1,2-DCE	70	6	450

µg/L = micrograms per liter
ppbv = parts per billion by volume

Preliminary cleanup goals for TPH-D in soil were also derived from existing standards developed for Beale AFB. Risk-based cleanup levels for soils contaminated with petroleum hydrocarbons were applied to the Beale AFB Underground Storage Tank Remediation Program (Metcalf and Eddy, 1996). These cleanup levels were developed to minimize the potential for any groundwater impacts from TPH-D contamination in soil. The cleanup levels are assessed using the deionized water waste extraction test (DI WET) and may be set at different levels depending on the depth of contamination and groundwater. The cleanup levels for TPH-D in soil at Site 10 are provided in Table ES-3.

TABLE ES-3
Preliminary Cleanup Levels in Soil for TPH-D
Site 10 Feasibility Study, Beale AFB, California

Analyte	Soil Cleanup Level[a] (DI WET mg/L)	Applicability
Diesel-range Organics (TPH-D)	1	For contamination within the area-specific vadose zone buffer[b] defined in Metcalf & Eddy (1996).
	0.01 (nondetect)	For contamination below the buffer.

[a]Based on analysis for TPH-D using the DI WET. The cleanup levels were calculated as (Water Quality Goal) X (EAF)/10.

[b]The site-specific buffer at Site 10, based on the modeling performed by Metcalf & Eddy, is approximately 22 feet thick. Assuming an average depth to groundwater of 40 feet below ground surface (ft bgs), the maximum depth that would still be above the buffer is 18 ft bgs.

DI WET = deionized water waste extraction test

mg/L = milligrams per liter

Site-specific conditions and limitations of TPH remedial technology may suggest that modification of these cleanup levels is warranted in the future. These levels are not necessary to achieve RAOs or comply with ARARs, but are adopted here to be considered if proven technically and economically feasible. Additional data are required to fully assess the feasibility of achieving these previously established cleanup goals for TPH-D at Site 10.

Risk-based preliminary cleanup goals were developed for PAH contamination in soils. Since there are multiple compounds classified as PAHs, a concentration limit for each individual compound was not developed. The cleanup goals for PAH contamination in soil are to reduce potential elevated human cancer risk to less than one case per million lifetime exposures under a residential scenario.

Published water quality objectives for groundwater were used as the basis for establishing preliminary cleanup goals for groundwater at Site 10. Multiple water quality objectives were considered for potential use as preliminary cleanup goals. Potential preliminary cleanup goals for groundwater are included in Table ES-4.

Development and Screening of Alternatives

Screening of potential remedial technologies and process options resulted in the development of various remedial alternatives for Site 10. Alternatives were developed based on their applicability to soil and soil vapor, source area groundwater, or the more distal portion of the groundwater contaminant plume. For purposes of the FS evaluation of alternatives, the source area is defined as the groundwater that is contaminated with TCE at concentrations greater than 100 µg/L. The source area includes approximately 9 acres, and the distal portion of the TCE plume covers approximately 60 acres. Independent evaluation of high-concentration areas and distal portions of the plume seeks to apply source area and distal remedies in such a way that optimal treatment and economic efficiencies would be realized based on the particular technology evaluated. The remedial alternatives developed using this approach can be combined to form a complete remedy for the site.

A brief description of technologies and process options used as the basis for alternative development is described below. The alternatives developed on this basis are also briefly described.

TABLE ES-4
Potential Preliminary Cleanup Goals for Groundwater
Sites 10 Feasibility Study, Beale AFB, California

Contaminant of Concern	Primary MCL[a] (µg/L)	PRG[b] (µg/L)	PHG[c] (µg/L)	Background (µg/L)
Benzene	1[d]	0.35	0.14	ND
Chloroform	100[e]	0.16	--	ND
Cis-1,2-DCE	6[d]	61	--	ND
Methyl-tert-butyl-ether (MTBE)	13[d]	20	13	ND
PCE	5	1.1	0.056	ND
Trans-1,2-DCE	10[d]	1,200	--	ND
TCE	5	1.6	0.8	ND

[a]Safe Drinking Water Act, Maximum Contaminant Level (MCL).

[b]U.S. Environmental Protection Agency Region IX Preliminary Remediation Goal (PRG).

[c]Office of Environmental Health Hazard Assessment Public Health Goal (PHG).

[d]California MCL, which is more stringent than the Federal MCL.

[e]For total trihalomethanes.

No Further Action

The No Further Action option serves as a baseline against which other options are compared. This action is required for consideration by the National Contingency Plan (NCP). It is evaluated to determine the risks to public health and the environment if no additional actions were taken. No additional attempt is made to satisfy the RAOs, and no remedial measures are implemented. No Further Action is retained as a possible remedial alternative for soil and groundwater.

Institutional Controls

Institutional actions are non-engineering methods by which access to contaminated groundwater or soil is physically restricted or regulated, and/or the contamination is monitored. The institutional controls process options (land use restrictions, land purchase, and groundwater monitoring) may be implemented in conjunction with other response actions. Institutional controls were considered as remedial alternatives for soil and groundwater.

Monitored Natural Attenuation

Natural attenuation of hydrocarbons, chlorinated solvents, and related compounds in soil and groundwater is defined as any combination of "physical, chemical, or biological processes that, under favorable conditions, act without human intervention to reduce the mass, toxicity, mobility, volume, or concentration of contaminants in soil or groundwater" (U.S. EPA, 1999). Monitored natural attenuation (MNA) was evaluated for groundwater in both the source and distal portions of the contaminant plume. The MNA alternatives included the addition of monitoring wells and monitoring parameters necessary to assess the effectiveness of MNA.

Containment

Containment is a technology that isolates, minimizes, reduces, or eliminates bulk migration of contaminants in the surface soil and/or subsurface environments. Containment systems such as soil capping are used to isolate high-concentration areas or source areas so that there is no longer a continuing source of material for migration in the dissolved phase or even potentially as free-phase material. Traditional containment systems included engineered soil capping or are composed of sheet metal walls or clay slurry walls that are placed over or keyed into a confining layer or less permeable material such as low permeability clay or bedrock. A soil capping alternative for soil was included in the screening analysis.

Alternatives for containment of groundwater were developed based on pump and treat technology as described further below.

Excavation and Disposal

Removal approaches include excavation of soil with treatment on- or offsite, or with disposal at an offsite facility. Soil excavation is normally conducted with the use of a backhoe or power shovel, or large rotary augers in some cases. Following excavation, soil can be treated or managed onsite or treated and/or disposed of offsite. An excavation alternative was developed to address PAH-contaminated soil for Site 10. This alternative includes excavation and disposal of approximately 13 cubic yards of soil.

Ex situ Treatment – Pump and Treat

Groundwater removal includes conventional groundwater extraction using wells, drains, or trenches. The groundwater collection option consists of actions taken to extract groundwater and provide treatment prior to disposal or reuse.

The groundwater treatment process option includes liquid-phase treatment to reduce toxicity, mobility, and/or volume of contaminants prior to use. The COCs in groundwater at Site 10 are amenable to both carbon adsorption and air stripping. In addition to ex situ treatment, pump and treat systems can prevent migration of contaminants by containment of groundwater.

Pump and treat alternatives were developed for both the source and distal areas of the contaminant plume. The source area pump and treat alternative included the installation of 24 extraction wells that are estimated to pump a total of 20 to 30 gallons per minute (gpm). The distal area pump and treat alternative included the installation of 33 extraction wells that are estimated to pump 670 gpm. In both cases, it was assumed that air stripping would be used for treatment of the extracted water.

In situ Treatment

In situ treatment involves the use of the subsurface environment to treat COCs. Through enhancement or alteration of the geochemical conditions, chlorinated volatile organic compounds (CVOC) can be treated to levels that meet regulatory guidelines. In situ technologies considered for Site 10 include bioventing, chemical oxidation, zero-valent granular iron (ZVI) (Ferox[SM] process), and bioremediation.

Soil Vapor Extraction

An SVE system, identified as the Site 10 North system, is currently in operation at Site 10. A second SVE system, identified as the Site 10 South system, was shut down after concentrations of VOCs reached cleanup goals. Further operation of the SVE system is being managed under the Long-term Operation and Maintenance (LTO&M) program. Its operation under that program until shutdown criteria are met is considered under the No Further Action Alternative. Subsequent operation or conversion to bioventing is discussed below.

Bioventing

Bioventing is an aerobic biological degradation technology. Wells are used to force air-containing oxygen into zones containing COCs to enhance aerobic biological degradation. This technology is similar to air sparging but differs in that air is forced into the subsurface under very low pressures to maintain oxygen levels required for aerobic bioremediation. The technology has proven useful for petroleum hydrocarbons and chlorinated compounds that degrade under aerobic conditions such as vinyl chloride. Cometabolic bioventing is a form of bioventing where a primary substrate or nutrient is added into the subsurface to enhance microbial growth to degrade COCs.

At Site 10, the existing SVE system could be converted back into a bioventing system to target the petroleum hydrocarbons that exist at this site. A bioventing alternative was developed for Site 10 soils.

Chemical Oxidation

Chemical oxidation involves injecting a solution of a strong oxidizing agent into a high-concentration zone or suspected dense non-aqueous phase liquid (DNAPL) zone to destroy the COCs in situ. Fenton's reagent and potassium permanganate have shown very promising results at a number of sites, leaving virtually no mass remaining after treatment of small test cells. The solution can be injected over a large area. A chemical oxidation alternative was developed for source area groundwater. Because of low permeability soils, this alternative requires approximately 900 injection points to implement effectively.

Zero-valent Iron

Permeable reactive barriers (PRBs) using ZVI have been used at a number of sites to treat groundwater containing CVOCs. A PRB is created by installing a wall of ZVI to intercept the flow of groundwater containing the CVOCs. Once ZVI is installed in the subsurface, groundwater flows through PRB under natural gradients, and no pumping or other aboveground operations are required. The ZVI is permeable and creates geochemical conditions that rapidly degrade the CVOCs in groundwater flowing through PRB. ZVI alternatives were developed for source area groundwater remediation and as a barrier to prevent contaminant migration at the leading edge of the plume. The source area alternative involved 250 injection points to treat the defined source area. Approximately 70 injection points would be required to construct a 1,000-foot passive barrier applied to the distal portion of the plume.

Bioremediation

Enhanced bioremediation includes adding soluble carbon substrates (lactate, alcohol, acetic acid), emulsified oil, or hydrogen releasing compounds (HRC) to the subsurface via active injection wells. These soluble organic carbon substrates are injected into the groundwater to stimulate natural anaerobic microorganisms to produce an anaerobic-reducing environment. The microbial activity is responsible for creating the anaerobic-reducing conditions that reduce CVOCs.

Enhanced bioremediation alternatives were developed for groundwater in the source area and distal portion of the plume. Modeling indicates that 13 injection points and 9 extraction wells could distribute an electron donor across the source zone. The flow rate in this system was projected to be approximately 30 gpm. Similar to ZVI, a barrier alternative was developed for the distal portion of the plume using enhanced bioremediation. Pumped water would be mixed with a long-lived electron donor and injected sequentially into one of six injection wells located in a north-south line along the distal end of the TCE plume. The model projects a flow rate of approximately 100 gpm would be needed to achieve adequate distribution of the injected solutions.

Tables ES-5 through ES-7 provide summaries of the alternatives evaluated at the screening level for Site 10, and the basis of their retention for detailed analysis or elimination from further consideration. To define the management area groundwater, alternatives will be preceded with a "S" or a "D" to denote source area or distal end or plume, respectively.

TABLE ES-5
Screening Level Summary for Soils
Sites 10 Feasibility Study, Beale AFB, California

	Screening Criteria			
Alternative	**Implementability**	**Effectiveness**	**Cost**	**Retained for Further Detailed Analysis**
1 - No Further Action	High – no additional construction required	Low	Very Low	**Retained, as required by U.S. EPA guidance**
2 – Institutional Controls	High	Low to Moderate – will be effective when used with other alternatives	Low	**Retained for use with other alternatives**
3 – Excavation	High – shallow excavation will be sufficient to remove PAHs in soil	Moderate – only deals with PAHs in soil, not petroleum hydrocarbons	Low capital and no O&M costs	Retained as part of Alternative 6
4 – Bioventing	Moderate to High – depending on equipment reconfiguration	Moderate – as it only deals with petroleum hydrocarbons	Moderate capital and O&M costs	Retained as part of Alternative 6
5 – Containment (Capping)	High – a highly effective exposure reduction method	Low to Moderate – as the capping is not as effective as excavation	Low to Moderate capital costs and High O&M costs	Not Retained
6 – Bioventing and Excavation	Moderate to High – depending on equipment reconfiguration for bioventing	Moderate to High – can be effective for both PAHs and petroleum hydrocarbons in soil	Moderate capital and O&M costs	**Retained**

TABLE ES-6
Screening Level Summary for Groundwater—Site 10 Source Area
Sites 10 Feasibility Study, Beale AFB, California

Alternative	Screening Criteria			Retained for Further Detailed Analysis
	Implementability	**Effectiveness**	**Cost**	
S-1 – No Further Action	High – no additional construction required	Low	Very Low	**Retained, as required by U.S. EPA guidance**
S-2 – Monitored Natural Attenuation	High – would require only additional analyses	Moderate – can be effective but depends on degree of natural attenuation	Low capital and Moderate O&M – long-term monitoring is required	**Retained**
S-3 – Groundwater Extraction and Ex situ Treatment (Pump and Treat)	Moderate to High – multiple extraction wells required	Low to Moderate – effective as a hydraulic control but may not achieve cleanup goals in reasonable time	High capital and Moderate O&M costs assuming discharge to sanitary sewer	**Retained**
S-4 – Chemical Oxidation	Moderate to High – depending on subsurface conditions	Low – source area concentrations are too low for this to be effective	Moderate to High capital and Moderate O&M costs	Not retained
S-5 – Enhanced Bioremediation Barrier	High – can be highly effective in reducing mass in the subsurface	Moderate to High – will need pilot test to evaluate recirculation in clay aquifer soils	Moderate capital costs and High O&M costs	**Retained**
S-6 – Ferox^{SM} Process	Moderate to High – depending on final number of injection points	Moderate – concerns regarding barrier continuity and longevity	High capital and Moderate to High O&M costs depending on longevity of iron	Not Retained

TABLE ES-7
Screening Level Summary for Groundwater—Distal End of Plume
Sites 10 Feasibility Study, Beale AFB, California

Alternative	Screening Criteria			Retained for Further Detailed Analysis
	Implementability	**Effectiveness**	**Cost**	
D-1 – No Further Action	High – no additional construction required	Low	Low	**Retained, as required by U.S. EPA guidance**
D-2 – Monitored Natural Attenuation	High – would require some additional wells and analyses	Moderate to High– can be effective but depends on degree of natural attenuation	Low capital and Moderate O&M – long-term monitoring is required	**Retained**
D-3 – Groundwater Extraction and Ex situ Treatment (Pump and Treat)	Low to Moderate – lack of options for disposal of treated water	High – will provide containment if sufficient pumping is maintained	Moderate capital and High O&M costs due to multiple wells and treatment plant operation	**Retained**

TABLE ES-7
Screening Level Summary for Groundwater—Distal End of Plume
Sites 10 Feasibility Study, Beale AFB, California

Alternative	Screening Criteria: Implementability	Effectiveness	Cost	Retained for Further Detailed Analysis
D-4 – Enhanced Bioremediation Barrier	High – can be used as a passive system with injection wells	Moderate – will need pilot test to evaluate the number of injection wells	Moderate capital costs and High O&M costs due to relatively high chemical use	**Retained**
D-5 – Ferox[SM] Process	Moderate to High – depending on number of injection points	Moderate – concerns regarding installation and longevity of barrier	High capital and Moderate to High O&M costs depending on longevity of iron	Not Retained

Detailed Comparison of Remedial Alternatives

The alternatives that were retained for detailed analysis were evaluated with respect to their effectiveness in meeting the following criteria:

1. Provide overall protection of human health and the environment
2. Comply with ARARs
3. Provide long-term effectiveness and permanence of the remedial action to minimize risks
4. Reduce toxicity, mobility, and volume through treatment
5. Meet short-term remediation goals, including minimization of adverse health, safety, and environmental impacts during remedial activities
6. Provide technical viability, reliability, and implementability
7. Provide cost-effectiveness and economic feasibility

Tables ES-8 through ES-10 provide a summary of each alternative's performance in meeting the above criteria.

The No Further Action Alternative was the least expensive option for the soil and groundwater remediation. It was also the least effective in protecting human health and the environment and generally did not comply with ARARs.

Institutional controls were evaluated independently of other alternatives but could be considered in combination with soil or groundwater alternatives to enhance their effectiveness. Institutional controls were considered effective for addressing PAH soil contamination if they were designed to prohibit future residential use of the site.

Bioventing and excavation of PAH soils was the most effective soil remedy evaluated for protection of human health and the environment. Capital and operating costs for this soil alternative are modest and were the highest cost of the evaluated soil alternatives.

TABLE ES-8
Comparison of Technology Alternatives for Soil
Site 10 Feasibility Study, Beale AFB, California

Feasibility Criteria	Description of Criteria	Technology Alternatives: 1 No Further Action	2 Institutional Controls	6 Bioventing and Excavation
Threshold Criteria				
Overall Protection of Human Health and the Environment[a]	Alternative achieves and maintains protection of human health and the environment.	Current SVE treatment provides protection to human and environmental exposure from soil gases, but does not remediate PAH contamination or extended TPH-D treatment.	Current SVE treatment minimizes human and environmental exposure from soil gases, and could address PAH risk.	Alternative provides protection to human health and the environment from both PAHs and petroleum hydrocarbons.
Compliance with ARARs	Ability of alternative to meet ARARs.	Potentially ARAR compliant if existing SVE remediation is considered. Does not comply with ARARs related to management of wastes that will remain in place.	Potentially ARAR compliant if existing SVE remediation is considered. Must be combined with ARAR-compliant groundwater alternative.	Fully ARAR compliant with soil cleanup. Must be combined with ARAR-compliant groundwater alternative.
Balancing Criteria				
Long-term Effectiveness	Ability of technology to be protective of human health and the environment without upset over the long term.	Effective for soil gases, moderately effective for petroleum hydrocarbons, but not effective for PAHs in surface soil.	Effective for soil gases, moderately effective for petroleum hydrocarbons, but not effective for PAHs in surface soil.	Effective over long term for VOCs, PAHs, and petroleum hydrocarbons.
Reduction of Toxicity, Mobility, and Volume through Treatment	Ability of alternative to reduce mobility, toxicity, and volume of regulated compounds through treatment.	Alternative reduces toxicity and volume of VOCs in vadose.	Alternative reduces toxicity and volume of VOCs in vadose.	Alternative reduces volume and mobility through in situ treatment and excavation and removal.
Short-term Effectiveness	Approximate time estimate required to reach effectiveness.	Effective immediately for VOCs, but not for PAHs or TPH-D.	Effective immediately for VOCs, but not for PAHs or TPH-D.	Effective immediately for VOCs, PAHs, and petroleum hydrocarbons once implemented in 3 to 6 months of SVE shutdown.
Implementation and Operational Difficulty				
1. Technical Complexity	Technical challenges with implementation.	Very low - SVE system is in place.	Very low.	Low - SVE re-conversion to bioventing is not technically challenging.
2. Compatibility	Technology compatible with land use, site constraints, and other technologies.	Very compatible - No impacts of implementation.	Very compatible - Administrative vs. construction/operation	Very compatible with currently used technologies, and excavated areas are limited.
3. Operation, Maintenance, and Monitoring Requirements	Requirements, challenges, and difficulties with operation, maintenance, and monitoring.	Low - No additional operation, maintenance, and monitoring requirements.	Low - No additional operation, maintenance, and monitoring requirements. Ongoing enforcement needed.	Low to moderate operation, maintenance, and monitoring requirements. Operation and maintenance conducted monthly.
	• Operation	• Low	• Low	• Low
	• Maintenance	• Low	• Low	• Moderate for bioventing
	• Monitoring	• Low	• Low	• Moderate for bioventing
4. Disposal	Are wastes generated requiring disposal on- or offsite once fully operational?	No significant waste produced.	No significant waste produced.	Excavated soil volume low (13 cubic yards).
5. Service Availability	Vendor and service availability for alternative.	Not applicable.	Yes - Professional support services are available for this alternative.	Yes - Vendors and services are available for all components of this alternative.
Cost	• Capital costs	• Zero	• Low ($24,000)	• Moderate ($164,000)
	• Operation and maintenance costs	• Very low	• Low ($7,000)	• Moderate ($41,000)
	• Net present value costs	• Very low	• Low ($111,000 - 20 years)	• Moderate ($375,000 - 6 years)
	• Total accumulated cost	• Very low	• Low ($151,000 - 20 years)	• Moderate ($404,000 - 6 years)

Notes:

Implementability criterion was subdivided into technical, operational, and service-related sub-criteria

[a]Overall protection relates to the ability of alternative to reduce, minimize, or eliminate direct exposure of COCs to humans

TABLE ES-9
Comparison of Technology Alternatives for Groundwater Source Area
Site 10 Feasibility Study, Beale AFB, California

Feasibility Criteria	Description of Criteria	Technology Alternatives S-1 No Further Action	S-2 Monitored Natural Attenuation	S-3 Groundwater Extraction and Ex situ Treatment (Pump and Treat)	S-5 Enhanced Bioremediation Barrier
Threshold Criteria					
Overall Protection of Human Health and the Environment[a]	Alternative achieves and maintains protection of human health and the environment.	Current SVE achieves and maintains protection of human health for soil vapor and diffuse flux from groundwater, NA unmonitored.	Current SVE achieves and maintains protection of human health for soil vapor and diffuse flux from groundwater; MNA evaluated for dissolved CVOCS.	Alternative provides protection of human health and the environment when combined with selected soil alternative.	Alternative provides protection of human health and the environment when combined with selected soil alternative.
Compliance with ARARs	Ability of alternative to meet ARARs.	Does not comply with ARARs requiring cleanup and abatement of contamination to levels technically and economically feasible.	Potentially ineffective approach for ARAR compliance as it may further degrade groundwater quality in currently unimpacted areas.	Effective source area containment remedy, but must be combined with ARAR-compliant remedy that addresses areas outside the source zone.	Effective source area treatment alternative, but must be combined with ARAR-compliant remedy that addresses areas outside the source zone.
Balancing Criteria					
Long-term Effectiveness	Ability of technology to be protective of human health and the environment without upset over the long term.	Potentially effective but no means to evaluate without monitoring NA process.	Potentially effective but will take 1 to 2 years to evaluate.	Effective hydraulic control over long term, but ineffective remediation system for attainment of cleanup goals in reasonable time.	Effective over long term for treatment of primary and secondary contaminants.
Reduction of Toxicity, Mobility, and Volume through Treatment	Ability of alternative to reduce mobility, toxicity, and volume of regulated compounds through treatment	Alternative potentially reduces toxicity and volume of CVOCs over the long term, but may increase volume and mobility initially. No monitoring to track effectiveness.	Alternative potentially reduces toxicity and volume of CVOCs over the long term, but may increase volume and mobility initially.	Alternative reduces toxicity and mobility through extraction and ex situ treatment.	Alternative reduces toxicity, volume, and mobility through enhancement of biological reductive dechlorination of CVOCs.
Short-term Effectiveness	Approximate time estimate required to reach effectiveness.	Not anticipated to be effective over the short term.	Not anticipated to be effective over the short term.	Effective over the short term for containment. Ineffective for restoration of aquifer in the short term.	Potentially effective over the short term once operational.
Implementation and Operational Difficulty					
1. Technical Complexity	Technical challenges with implementation.	Very low.	Very low - Expanded set of monitoring parameters and evaluation of MNA.	Low to moderate - Groundwater extraction and treatment is well established.	Low to moderate - Largest challenge is mixing groundwater amendments in treatment zone.
2. Compatibility	Technology compatible with land use, site constraints, and other technologies.	Very compatible.	Very compatible - Expansion to existing system.	Somewhat compatible - Water discharge and reuse is a concern.	Very compatible given water is injected to mix electron donor amendments.
3. Operation, Maintenance, and Monitoring Requirements	Requirements, challenges, and difficulties with operation, maintenance, and monitoring.	Not applicable.	Moderate monitoring requirements to evaluate MNA initially.	Moderate operation, maintenance and monitoring requirements. Includes wells, pumps, controls, water disposal.	Moderate operation, maintenance, and monitoring requirements. Added operation and maintenance for chemical feed system. No water disposal requirements.
	• Operation	• Low	• Low	• Moderate	• Low
	• Maintenance	• Low	• Low	• Moderate	• Moderate
	• Monitoring	• Low	• Low	• Moderate	• Moderate
4. Disposal	Are wastes generated requiring disposal on- or offsite once fully operational?	No	Low - IDW for monitoring wells.	Yes - 20 to 30 gpm of treated water. IDW for wells.	Low - IDW for extraction/injection wells.
5. Service Availability	Vendor and service availability for alternative.	Not applicable.	Yes - Vendors and services are available for all components of this alternative.	Yes - Vendors and services are available for all components of this alternative.	Yes - Vendors and services are available for all components of this alternative.
Cost	• Capital costs	• Very low	• Low ($102,000)	• Moderate ($791,000)	• Moderate ($850,000)
	• Operation and maintenance costs	• Very low	• Moderate ($67,00)	• Moderate ($78,000)	• High ($142,000)
	• Net present value costs	• Very low	• Moderate ($1,553,000 - 50 years).	• High ($2,478,000 - 50 years)	• Moderate ($1,483,000 - 5 years)
	• Total accumulated cost	• Very low	• Moderate ($3,422,000 - 50 years).	• High ($4,651,000 - 50 years)	• Moderate ($1,559,000 - 5 years)

Notes:
Implementability criterion was subdivided into technical, operational, and service-related sub-criteria
[a]Overall protection relates to the ability of alternative to reduce, minimize, or eliminate direct exposure of COCs to humans

TABLE ES-10
Comparison of Technology Alternatives for Distal Groundwater Plume
Site 10 Feasibility Study, Beale AFB, California

		Technology Alternatives			
Feasibility Criteria	**Description of Criteria**	**D-1 No Further Action**	**D-2 Monitored Natural Attenuation**	**D-3 Groundwater Extraction and Ex situ Treatment (Pump and Treat)**	**D-4 Enhanced Bioremediation Barrier**
Threshold Criteria					
Overall Protection of Human Health and the Environment[a]	Alternative achieves and maintains protection of human health and the environment.	Natural attenuation and potential plume migration would not be monitored.	Potentially effective in reducing or eliminating regulated CVOCs in groundwater when combined with source area remedy; potential plume migration would be monitored.	Could be effective in controlling migration of contaminated groundwater; would take significant time to reduce concentrations to levels protective of human health and the environment.	Could be effective in eliminating risks in distal portion of plume by dechlorinating CVOC contaminants to nonregulated, naturally occurring compounds.
Compliance with ARARs	Ability of alternative to meet ARARs.	Does not comply with ARARs requiring cleanup and abatement of contamination to levels technically and economically feasible.	Effective approach for ARAR compliance, especially if combined with contaminant mass reduction in high-concentration areas.	Would comply with ARARs, large volume of water requiring disposal or reuse may present difficulties with waste disposal requirements. Design alterations or mitigation measures may be needed to avoid impacts to vernal pools.	ARAR compliant. May not require an active source area remedy in combination depending on effectiveness of barrier.
Balancing Criteria					
Long-term Effectiveness	Ability of technology to be protective of human health and the environment without upset over the long term.	Potentially effective, but no means to evaluate without monitoring NA process.	Potentially effective in reducing contaminant concentrations over the long term when combined with source area remedy.	Effective hydraulic control over long term, but not an effective remediation system for the long term.	Effective over long term for treatment of primary and secondary breakdown compounds.
Reduction of Toxicity, Mobility, and Volume through Treatment	Ability of alternative to reduce mobility, toxicity, and volume of regulated compounds through treatment.	Alternative potentially reduces toxicity and volume of CVOCs over the long term.	Alternative potentially reduces toxicity and volume of CVOCs over the long term.	Alternative reduces toxicity and mobility through extraction and ex situ treatment.	Alternative reduces toxicity, volume, and mobility through enhancement of biological reductive dechlorination.
Short-term Effectiveness	Approximate time estimate required to reach effectiveness.	Not anticipated to be effective over the short term.	Potentially effective over the short term, dependent on NA rates and plume dynamics.	Effective for containment over the short term once implemented; reduction of toxicity of contaminated groundwater would occur over the long term.	Effective over the short term as a contaminant migration barrier once operational.
Implementation and Operational Difficulty					
1. Technical Complexity	Technical challenges with implementation.	Very low.	Very low - Expanded set of monitoring parameters and evaluation of MNA.	Moderate to high - Large area impacted, up to 700 gpm of treated wastewater to manage.	Moderate - Largest challenge is mixing ground-water amendments in treatment zone.
2. Compatibility	Technology compatible with land use, site constraints, and other technologies.	Very compatible.	Very compatible - Expansion to existing system.	May not be compatible - Disposal of treated water and disruption of vernal pool habitat.	Compatible given water is injected to mix electron donor amendments.
3. Operation, Maintenance, and Monitoring Requirements	Requirements, challenges, and difficulty with operation, maintenance, and monitoring.	Not applicable.	Low operation, maintenance and monitoring requirements. Monitoring more frequent initially.	Moderate operation, maintenance, and monitor-ing requirements. Many wells, treatment system, significant wastewater conveyance pipeline.	Moderate operation, maintenance and monitoring requirements. Extraction and injection wells, chemical mixing and delivery.
	• Operation • Maintenance • Monitoring	• Low • Low • Low	• Low • Low • Low	• Moderate • Moderate • Moderate	• Low • Moderate • Moderate
4. Disposal	Are wastes generated requiring disposal on- or offsite once fully operational?	No.	Low - IDW from well installation.	Yes - 670 gpm of treated wastewater, IDW from well installation.	Low - IDW from well installation.
5. Service Availability	Vendor and service availability for alternative.	Not applicable.	Yes - Vendors and services are available for all components of this alternative.	Yes - Vendors and services are available for all components of this alternative.	Yes - Vendors and services are available for all components of this alternative.
Cost	• Capital costs • Operation and maintenance costs • Net present value costs • Total accumulated cost	• Very low • Very low • Very low • Very low	• Low ($132,000) • Moderate ($68,000) • Moderate ($1,315,000 - 30 years) • Moderate ($2,159,000 - 30 years)	• High ($2,716,000) • High ($154,000) • High ($5,403,000 - 30 years) • High ($7,320,000 - 30 years)	• Moderate ($550,000) • High ($143,000) • High ($2,802,000 - 25 years) • High ($4,115,000 - 25 years)

Notes:
Implementability criterion was subdivided into technical, operational, and service-related sub-criteria
[a]Overall protection relates to the ability of alternative to reduce, minimize, or eliminate direct exposure of COCs to humans

MNA is a potentially effective and ARAR-compliant remedy for the distal portion of the plume. This is especially true if combined with a source area mass removal alternative. However, the natural degradation processes are not well understood at Site 10 and should be further evaluated to confirm its potential. MNA applied to the source zone could also be effective, although there is higher risk of significant contaminant migration and extended time to attain cleanup goals.

Pump and treat options for the source area and distal portions of the plume were considered protective of human health and the environment through containment of contaminated groundwater. However, the time required to achieve cleanup goals may be significantly longer than other active alternatives evaluated. Costs of pump and treat systems are high, especially for the distal portion of the plume, primarily due to the large volume of water that must be disposed of or reused.

Enhanced bioremediation of the source area has the potential to be very effective in reducing toxicity and volume through treatment if subsurface conditions allow for adequate distribution of electron donor and are conducive to anaerobic reductive dechlorination. Capital costs are moderate, but annual operational costs could be significant if cleanup objectives are not achieved within projected timeframes. The enhanced bioremediation barrier alternative applied to the distal portion of the plume would provide additional assurances over MNA that contaminants would not migrate offsite. However, MNA could be equally as effective depending on the current rate of natural attenuation processes that affect contaminant migration. Moreover, the effectiveness of the enhanced bioremediation barrier alternative is reliant on proper distribution and longevity of electron donor in the subsurface.

Final Decisions

The preferred remedial alternatives for soil and groundwater will be selected and presented in the Proposed Plan. The Proposed Plan provides the information needed for the public to understand and to comment on the merits of the preferred alternatives. A public meeting will be held to formally present the preferred alternatives and to obtain public comment on them. After the public comments are received, the final plan is issued in the ROD, a legal document that details the actions to be taken at each site.